Tilt Rotor Descent Aerodynamics

Mark D. Betzina

A small-scale experimental investigation was conducted in the Ames 80- by 120-Foot Wind Tunnel with the objective of studying the aerodynamic characteristics of a tilt rotor at high descent angles in helicopter mode. When helicopter rotors descend vertically or at high descent angles, they can enter a flow condition called the vortex ring state (VRS). VRS occurs when the descent velocity approaches the induced rotor-wake velocity, allowing recirculation of the wake through the rotor disk. VRS is characterized by rotor thrust loss and thrust oscillations. It can be dangerous, because the descent rate accelerates as the rotor thrust declines, and the helicopter may not have sufficient power available to slow the descent. Helicopter pilots typically avoid VRS by limiting descent rate at low forward speeds.

Tilt rotors have unique characteristics that are different from those of helicopter rotors, including higher disk loading, higher blade twist, and interactions between the two rotor wakes and with the wing. But no prior research had been done to determine if these characteristics cause tilt rotors to respond differently in VRS. Therefore, specific objectives of the current study were to determine the region of the flight envelope where VRS occurs and to determine if tilt rotors behave differently from helicopter rotors in VRS.

A single, 4-foot-diameter, three-bladed rotor, with twist and solidity similar to those of current tilt-rotor aircraft, was tested with an image plane to simulate the mean effect of a second rotor. Rotor performance data were obtained over a wide range of simulated flight conditions from horizontal flight to vertical descent.

Figure 1 shows the collective pitch required to maintain a constant rotor thrust coefficient as a function of descent angle at an advance ratio of 0.08. The required rotor power has the same trend as the collective pitch. Large increases in collective pitch and power are required at descent angles between 40 and 60 degrees because of the thrust reduction that occurs in VRS. This thrust reduction was found to begin at descent angles between 20 and 40 degrees, depending on the collective pitch and advance ratio. This behavior could affect a tilt-rotor aircraft's response to the flight controls in VRS. Flight control simulations are required to determine the significance of these effects on aircraft controllability.

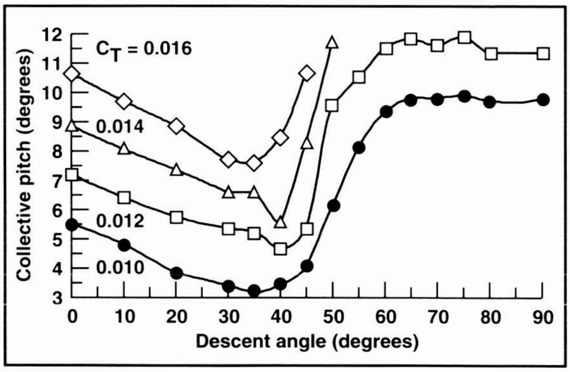

Fig. 1. Collective pitch required to maintain constant rotor thrust.

Rotor thrust fluctuations accompany the mean thrust reductions in VRS. Figure 2 shows the magnitude of the rotor thrust fluctuations, the larger symbols indicating larger fluctuations. The data are plotted on a graph of normalized descent velocity versus normalized horizontal velocity, indicating the region of the flight envelope where thrust fluctuations occur. As shown, significant thrust fluctuations are found at descent angles of 30 degrees and higher. The largest thrust fluctuations, up to 52% of the mean thrust, occur in the shaded region at descent angles between 50 and 80 degrees. The fluctuations have a very low frequency and

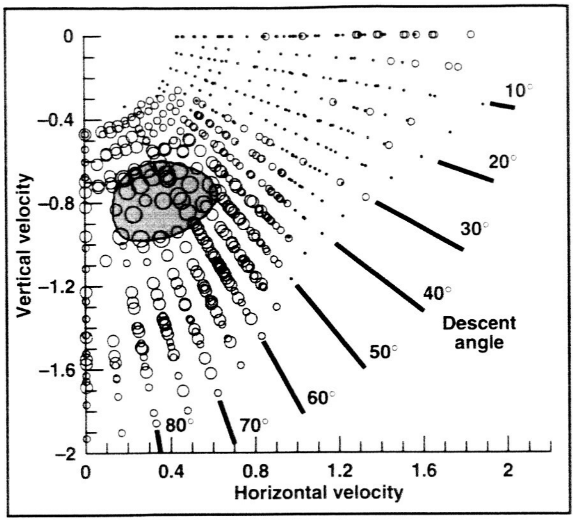

Fig. 2. Oscillatory rotor thrust magnitudes.

could cause low-frequency thrust and roll fluctuations in tilt-rotor aircraft operating in VRS.

Although these characteristics are generally similar to those of helicopter rotors, the data indicate that tilt rotors may experience larger thrust reductions and greater thrust fluctuations than single helicopter rotors. Because the image plane may not accurately represent the effects of a second rotor, further research is required to determine these characteristics for two side-by-side rotors.

Point of Contact: Mark Betzina
(650) 604-5106
mbetzina@mail.arc.nasa.gov

A Comparison of Transmission Vibration Responses from OH-58C and AH-1 Helicopters

Edward M. Huff, Irem Y. Tumer, Marianne Mosher

As part of NASA's overall goal to improve aviation safety, fundamental research is being conducted to support the development of systems that monitor critical rotating components, such as those found in helicopter gearboxes and aircraft engines. Damage detection based on observed patterns of surface vibration requires insight into the statistical properties of complex signals that are produced by interacting elements within the system, as well as the effects of in-flight maneuvering.

Table 1 shows the tendency of vibration signals to remain constant (i.e., stationary) over 34-second recording intervals. The extent of nonstationarity is dependent on both maneuver state and aircraft type, which other evidence suggests are related to vehicle weight and engine torque variations. Hence, these findings provide an essential link for developing damage-detection algorithms that are not deceived by nonstationarity into making costly "false-alarms."

In FY2000 we conducted the first flight tests of the Ames' OH-58C aircraft and made comparisons of vibratory signals with an identical transmission tested at the NASA Glenn Helicopter Transmission Facility. Table 2 shows the results of an effort to parse signal energy for transmission component sources from these two tests. This work reveals similarities and differences between real flight and test rig vibration signals, information that is necessary to develop damage-detection algorithms with low false-alarm rates and high fault detection. Work in this area was reported at the American Helicopter Society Annual National Forum in 2000.

Point of Contact: Edward Huff
(650) 604-4870
ehuff@mail.arc.nasa.gov